VOLUME 3, PART 1, CHAPTER 2. COSMONAUT (ASTRONAUT) TRAINING

Doctor M. M. Link and Doctor N. Gurovskiy

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16. Abstract

A presentation of the methodological approach to biomedical and preflight spacecraft crew training. Comparisons are drawn between U.S. and Soviet procedures, inasmuch as they are similar.

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VOLUME 3, PART 1, CHAPTER 2. COSMONAUT (ASTRONAUT) TRAINING

Doctor M. M. Link and Doctor N. Gurovskiy

Introduction

In this chapter, which is based upon a survey of the Soviet and American /2* scientific-technical literature, principal attention is concentrated on methods of medical and biological training and preflight training of spacecraft crews. Such an approach seems logical in connection with the fact that the scientists of both countries support approximately similar methods of training and conditioning, utilizing the experience which has been accumulated as the result of manned high velocity and high altitude aircraft flights. Each country extrapolates the available data to successive long term flights and predicts the possible reactions of man, as well as builds theoretical models of human adaptation to the new environment after the man leaves the Earth and sets out on a spaceflight. Moreover, the experience of actual spaceflights provides an evergrowing volume of information for scientists and specialists working in this field; on the basis of this information one can predict the state of health of a man and develop the necessary measures for supporting his vital activity with the promise of an increase in the duration of spaceflights.

Medical and biological training of cosmonauts and astronauts is a dynamic process which increases the resistance of the organism to the effect of space-flight factors. Such factors include the following: 1. Factors of outer space (nearly complete vacuum, cosmic radiation, etc.), 2. Factors related to the dynamics of spacecraft flight (noise, vibration, weightlessness, acceleration, vestibular stimuli), and, 3. Other factors, which depend upon the peculiarities of the flight and the state of a man in the cabin of a spacecraft (isolation, /3 artificial atmosphere, peculiarities of nourishment, the unique psychological background, neuro-emotional stress).

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*Numbers in margin indicate pagination in the foreign text.

Inasmuch as the technical systems provide protection of the cosmonaut (astronaut) from the effect of factors of the first group, as well as noise, vibration, and certain others, it is unnecessary to achieve an increase in the resistance of the organism by the aid of medical and biological conditioning to these factors. However, special conditioning for increasing the resistance of the organism to the effect of accelerations and, particularly, weightlessness is obligatory. (In the program of medical-biological training of Soviet cosmonauts, certain types of one-time factors directed primarily at a study of the individual capacities of the organism and its reserve capacities also figure in. These include long, 10-day trials in the soundproof chamber, and trial runs in the thermochamber).

Systematic conditioning provides more aircraft flights, including those in the Kepler parabola, rotation in the centrifuge, vestibular conditioning, and general physiological training and combined investigation-training in the spacecraft simulator.

The program of the American astronauts is reminiscent of the Soviet program; it is also based upon the experience of actual spaceflights and on individual approaches and characteristics of the organisms of the crew members.

In formulating the special programs of training, the goals and tasks of the space experiments were given attention, as well as the characteristics and physical condition of the participants and the possible forms of activity of the cosmonauts (astronauts) during various stages of the spaceflight. The training programs provided for multiply and systematically employing active factors, gradually increasing the intensity of the stimuli, and individual /4
characteristics of the cosmonauts were taken into account when determining the optimal loads and intervals between series of conditioning sessions.

The following persons participated in preparing the materials of this chapter ..... [Translator's Note: part of text appears to be missing] USA and Doctor T. V. Krupina, I. I. Bryanov — USSR, for which the authors give them their sincere thanks.

Medical-Biological Training

One of the elements of training Soviet cosmonauts for the first flights was trials in the silence chamber. The goal of a long term test of cosmonauts in the silence chamber was "a study of the state of the neuro-psychological sphere and the physiological reactions, determination of the human capacity exactly to accomplish tasks within the framework dictated by the activity" (5b). During the investigations of the cosmonauts in the silence chambers, both isolation was provided as well as creation of conditions of relative hypodynamia. The cosmonauts lived and worked according to an altered diurnal schedule "work-rest", corresponding to realistic conditions of spaceflights; a complex method for recording the medical-biological information was devised, thanks to which it became possible to conduct experimental psychological investigations.

The Soviet authors (16b, 17b, 18b, 4b, 6b) cite experimental data on the functional changes which were observed among certain Soviet cosmonauts during the experiments in the silence chamber. During the process it was noted that all the subjects were observed to have a high level of emotional-psychological stability and adaptive capacities. The time of stay in the chamber was not uniform, for example, V. V. Tereshkova spent 7 days there, while V. G. Bykovskiy spent 10 days. The differences in the time of staying in the chamber were due to quite a number of circumstances, including the proposed duration /5 of the flight.

In the process of investigations in the silence chamber, special complexes of physical exercises were tested which proved effective. A whole series of special devices and procedures were suggested; these included the bicycle ergometer, rubber expanders, and the system of inertial and isometric exercises (2b). Tested during 9 long term experiments, these devices demonstrated the positive effect with respect to preventing the undesirable consequences of hypokinesis and were recommended for use during an actual spaceflight.

The first groups of Soviet cosmonauts and American astronauts went through special conditioning in thermal chambers with an increased temperature. These conditioning sessions sought a two-fold goal: to increase the resistance of the organism to the temperature factor (an increase in temperature in the cabins

of spacecraft was considered a probable emergency situation), and to determine the individual reaction of the organism to a set thermal load. As a result of the investigations which were conducted, the Soviet authors (1b) recommended using exposure to a temperature of 60° as a functional heat test for undressed subjects.

Primary attention was paid to conditioning cosmonauts (astronauts) to staying under conditions of weightlessness — the primary unknown factor of spaceflight which could not be duplicated other than during the flight of high velocity aircraft along a Kepler trajectory. An investigation of the problem of using these flights for conditioning cosmonauts was conducted by American and Soviet scientists (24b) at the end of the 1950s.

It was established that the reaction of a man to short term (several tenths /6 of seconds) weightlessness is individual and that all subjects could be divided into 3 groups in accordance with their feeling and conduct in weightlessness: 1, persons who, during weightlessness, felt good; 2, persons who experienced illusory sensations which disappeared after 12 to 15 exposures, and 3, persons in whom symptoms of discomfort immediately developed and who underwent adaptation with difficulty.

Extremely significant was the fact that in the process of carrying out repeat flights along the Kepler parabola, most persons with a diminished tolerance to weightlessness gradually adapted to this factor.

The investigations of L. A. Kitayev-Smyk and I. A. Kolosov (8b, 9b) demonstrated that statokinetic disorders in flight personnel were less pronounced and more rapidly disappeared during repeated exposure than among nonflying personnel. For example, sensory disorders among flight personnel completely vanish after 12 exposures to weightlessness; among nonflying personnel, more than 30 repetitions were necessary to achieve this goal.

The possibility of adaptation to short term weightlessness was the basis for conducting conditioning of cosmonauts (astronauts) in real aircraft in flights along the Kepler trajectory. Conditioning was carried out both with the cosmonauts secured in their working place, and with their free drifting in the cabins of large aircraft. True, in these investigations Soviet and

American scientists took full cognizance of the significant differences between physiological reactions to short term and prolonged weightlessness. In the first instance, the effect was primarily addressed to the statokinetic analyzer and neuro-emotional sphere of the cosmonauts, while in the second dominant sig- /7
nificance was acquired by changes with respect to the cardiovascular system and the metabolic processes. Nevertheless, the flights along the Kepler trajectory not only made it possible to estimate the predisposition of the cosmonauts to vestibulo-vegetative disorders, but also to decrease the degree of the unfavorable reactions by means of adequate conditioning, which in the final analysis could prove useful in actual spaceflight as well.

Proportional to the accumulation of experience of manned spaceflights, flights aboard aircraft along the Kepler trajectory began to acquire character of test flights (for certain aggregates and systems whose working capacity in weightlessness was doubtful), and training sessions from the viewpoint of developing in the cosmonauts skill in carrying out certain operations in weightlessness.

In order to ensure adaptation of the physiological systems of man to the effect of transverse accelerations during spaceflight, the training system of Soviet cosmonauts and American astronauts included a special cycle of familiarizing and conditioning rotations in the centrifuge. During rotations in the centrifuge, the individual resistance of the organism to accelations of varying intensity was determined and measures were taken to increase this resistance.

The fact should be noted that both cosmonauts and astronauts positively evaluated preflight conditioning on the centrifuge. The general strengthening of the organism, as well as the development of corresponding skills in voluntary tensing of muscles of the leg and abdominal press — all this significantly increases the resistance to acceleration. Observations of the reactions of the organism during the action of g-forces lay at the basis of development of the conditioning system. The Soviet cosmonauts were subjected to exposure to transverse accelerations of a magnitude of 7.9 and 10 [Translator's Note: possibly 7, 9 and 10].

V. I. Stepantsov and A. V. Yeremin (19b) showed that conditioning on the /8
centrifuge is particularly effective in those cases when the original tolerance

of the man to this factor was low. Most effective were conditioning regimes based on the principle of a gradual increase in load with simultaneous increase of the intervals between rotations on the centrifuge. The Soviet cosmonauts first encountered vestibulo-vegetative disorders (motion sickness). The symptoms of motion sickness were observed in the pilot of the "Vostok-2" spacecraft, G. S. Titov. In connection with this, in the Soviet program of medical-biological training a large place was occupied by vestibular conditioning. The special programs of conditioning, which were always strictly individual, included active and passive methods. Methods of active conditioning include physical exercises, including exercises on gymnastic devices, passive conditioning does not provide for activity on the part of the person being conditioned and consists in swinging on simple and quadra support swings, rotation on special devices, etc. (15b).

Conditioning proved effective with gastrointestinal symptoms of motion sickness (success in 50% of the cases), and slightly effective when there were nervous and cardiovascular symptoms. Naturally, when conducting the conditioning exercises the individual characteristics of the person being conditioned have to be taken into account.

In the conditioning programs of the Soviet cosmonauts physical training was specially delineated, inasmuch as it is a nonspecific method for increasing the resistance of the organism to the effect of most spaceflight factors.

When setting up the program for physical training of Soviet cosmonauts, /9
in addition to group exercises, a significant place was assigned in the individual program taking into account the characteristics of the organism in the interest of the cosmonaut.

The development of space navigation, and the appearance of spacecraft whose crews include specialists of various professions determined the differentiation of tasks of each crew member and the inclusion in the crew of cosmonaut engineers and scientists of various professions.

In the works of N. N. Gurovskiy et al. (6.b), it is pointed out that their preflight training differed from the training of pilots. There was a change with respect to easing the requirements made on their state of health. The

characteristic peculiarity of this category of cosmonauts was lower physical conditioning and older age.

All of these characteristics had to be taken into account when setting up the program for training the cosmonaut investigators. Thus, for example, although particular significance attached to improving such qualities as spatial orientation in the capacity to observe moving points of orientation for the cosmonaut pilot (the spacecraft commander), for other crew members this does not necessarily have primary significance. However, tolerance for dynamic flight factors (weightlessness, g-forces) should be high among all crew members.

A characteristic of training cosmonaut investigators in the Soviet Union also consists in that the first stage of this training is carried out without interruption in basic work (for example, a physician in the clinic or institute, an engineer or astronomer in his department). At this stage a significant place is given physical conditioning, vestibular conditioning, and staying in the environment of a moderately high mountain. Only after this do the cosmonauts of this category proceed to conditioning as part of the crew; this conditioning /10 is conducted with such persons freed of their primary duties in work (6b).

In the United States of America the program of group preflight training, prior to the first suborbital flight, was obligatory for each pilot (and standby pilot), and this situation is maintained to the present day. All members of the detachment of astronauts participated in special and general training and simultaneously went through a limited course of conditioning in the mountains, which was a part of the general program.

In the first American program, whose goal was training a man to participate in spaceflight for the "Mercury" program, methods of training were employed which were considered neither new nor unique since they were widely used up to then in aviation in training pilots. Nevertheless, the characteristics of work in realizing the flight program also left a certain mark on training cosmonauts. Thus, for example inasmuch as the program did not have provision for mass training of astronauts, the seven selected candidates went through a specialized training course which was absent in the more general aviation programs. Moreover, all of these selected candidates were experienced pilots and test pilots,

people who could imagine the nature of spaceflights. In connection with this, the overall volume of mandatory training could have been diminished and the accent could have been placed on individual initiative and the personal responsibility of the candidates for their preparation.

Each astronaut selected on his own individual methods of maintaining normal physical status; these included water skiing, exercising on the "batut" [Translator's Note: term unidentified], etc. Not long ago, for increasing the vestibular and statokinetic resistance, various styles of swimming in the water, particularly the crawl with rotation along the longitudinal axis of the body were recommended. Third, the program of training in the spacecraft simulator constantly changed inasmuch as the spacecraft in which the astronauts had to work was in a state of development and was constantly undergoing modification. The program of training also had to dynamically accompany the real process of development of the spacecraft. Training sessions were frequently combined with systems tests in order to evaluate both the onboard equipment and the individual equipment of crew members. It should be noted that this third fact also fully pertained to the training of Soviet cosmonauts for the first flights in the "Vostok" and "Voskhod" programs. As has already been noted, in training the American astronauts a certain role was assigned to staying in a moderately high mountain environment. The investigations conducted in the USSR affirm the validity of this form of cosmonaut training. It was shown that acclimatization to moderately high altitudes makes possible an increase in the resistance of the organism to accelerations and hypoxia and increases the physical working capacity. Moreover, a stay in the mountains is convenient to use for psychological training of the crews for actions under complex conditions and for checking their personal qualities.

In the system of training cosmonauts (astronauts), an important place is occupied by training sessions on special simulator devices, among which a specific one is a complex of simulating methods ensuring the development of professional skills in controlling the spacecraft and its systems.

On the strength of the fact that there have not yet been created and will hardly be created in the near future spacecraft trainers, intended to train

cosmonauts in flight (as there are in flight practice), terrestrial simulators /12
support the entire volume of development of necessary skills in cosmonauts.

A significant peculiarity of creating simulators designed to train crews for the first spaceflights, or to develop skills of activity, and planned first (docking, entering open space, landing on Moon, etc.) consists in the fact that their development must precede the actual accomplishment of operations in space. Therefore, the theoretical calculations and the intuition of designers and cosmonauts had to compensate for the absence of experience.

Training facilities, with respect to their purpose, tasks which can be worked out on them, effectiveness, and design differ greatly.

All training facilities can be divided into simulators and facilities for training the organisms of the cosmonauts for conditions of spaceflight, and simulators for developing professional skills in controlling the spacecraft and its systems. (25b, 26b).

In addition to this, there can be combined simulators on which cosmonauts are prepared for professional activity in combination with preparing the organism for extremal flight factors.

The first group includes simulators and facilities for physical and special training (centrifuges, gymnastic facilities, "batut" [Translator's Note: term unidentified], treadmill, landing simulators, aircraft, etc.), as well as environmental simulators (pressure chambers, silence chambers, aircraft for flights along the Kepler trajectory, etc.).

The second group includes simulators for developing professional control skills (navigational, communications, approach and docking, landing, life support system simulators, etc.).

The complex simulator combines in itself many individual simulators of both /13
groups.

We have already dwelt on training the organism of cosmonauts to endure flight factors and particularly on the facilities used, therefore we shall now dwell on training cosmonauts to control the spacecraft and its systems.

In training the first group of Soviet cosmonauts, their training in spacecraft control was carried out on a simulator which provides development and reinforcement of skills in manual orientation and manual spacecraft descent. It included an optical orientator, a course, pitch and yaw control stick, an engineer control, planetaria, information and instruments, a computer for piloting in navigational parameters, a flight dynamics computer, a trajectory kinematics and engine installations dynamics, exercise and a simulator control panel.

Such a system of simulators of control is general for craft of any type; it enables the cosmonaut to work on the Earth on a real time scale and to simulate the actual parameters of movement of the spacecraft with respect to the Earth and the planets.

Naturally, the instruments used in such devices change dependent upon their degree of perfection. Such simulators were used when training Soviet cosmonauts for other programs.

During training of the "Soyuz" and "Salyut" programs, besides this, a significant place was occupied by training sessions on special simulators providing for the development of skills of docking spacecraft in space. They were based upon the actual approach of two spacecraft models whose movement was controlled by the cosmonaut. By the aid of an optical system, movements were relayed to the indicators (the "Volga" simulator) and television screens. /14

A great deal of attention was paid training cosmonauts to control the spacecraft and its systems; during this process skills of basic operations were brought to the point of automatism, and various unforeseen factors, including emergency situations were also widely developed.

The special program on the simulator, mounted in an aircraft, was carried out by the cosmonauts in preparing for their exit into open space during flights along the Kepler parabola.

The conclusive stage of the cosmonauts' training was a test simulator run using a simulator model of the spacecraft. The cabin of this model was equipped with all the actual systems of life support, communications, medical indices recording and scientific apparatus.

Dimensions of this stage of training were as follow: developing and checking elements of the flight assignment, obtaining fundamental background data characterizing the condition of basic physiological functions during the use of actual spacecraft systems and on a time scale corresponding to the flight time scale. Moreover, a final check was made on the fit of individual gear and the food ration was improved. The cosmonaut completely accomplished the future flight program.

A significant amount of time in the cosmonauts' training was set aside for studying the spacecraft design, and the design of the carrier rocket and theoretical courses.

According to opinions of Soviet cosmonauts, the training sessions in the spacecraft model are extremely useful and most fully enable one to form a conception of the future spaceflight, to improve interaction of crew members during the accomplishment of various missions and to introduce the last corrections into this mission.

The American astronauts also undergo the required preflight training in /15
simulators and trainers.

At the beginning of the "Mercury" project, grave fears were caused among specialists by the effect of flight factors on the working capacity of the crew. Accordingly, crew training was structured primarily to duplicate the effect of such conditions as high g-forces, the absence of the force of gravity, heat, noise and "tumbling" of the spacecraft in flight.

The astronauts of the "Mercury" type spacecraft went through multiple training sessions with simulated spaceflight factors acting on their organisms. Particular worry was expressed in regard to the possibility of manually controlling the spacecraft during the effect of high g-forces at the moment of launch and entry of the spacecraft into the dense layers of the atmosphere. Therefore, the astronauts of the "Mercury" project participated in 4 programs with rotation on the centrifuge at the [U.S.] Naval Station Center for Scientific Developments of Aviation, Johnsville, Pennsylvania. The results of the flights showed that the factors and conditions of staying in a space environment did not have unfavorable effects on the working capacity of crew

members during 24 hours of flight. After this, the training programs for crews of the "Gemini" and "Apollo" spacecraft were reexamined and attention, to a great degree, was transferred to problems of accomplishing multiple and complex operations in space. The experience of flights in the "Mercury" project revealed and confirmed the significance of simulating the panorama observed by the crew in the spacecraft window; this aspect acquired particular significance for the flights of the "Gemini" and "Apollo" spacecraft. In the simulator of the "Mercury" spacecraft there was no duplication of adequate views from the /16
spacecraft window, and therefore primary effort in the subsequent "Gemini" program was directed toward correcting this situation. The realization of the importance of simulators and training devices forced the initiation of development of a simulator duplicating the full profile of flight of the "Gemini" and "Apollo" programs.

Each flight of the "Mercury" spacecraft was anticipated by a complete "playback" with the participation of the crew and ground personnel of the most important phases of flight; this was part of the program for preflight crew training.

Inasmuch as such training has shown itself to be an extremely effective means of developing the activity of astronauts and personnel of the ground support group, it was, doubtlessly, worked out and expanded for the flight programs of the "Gemini" and "Apollo" spacecraft.

In connection with maneuvers for approach and orbit in the "Gemini" program, in the simulator for the "Gemini" spacecraft an improved model of the visual indicator with infinite perspective was introduced; this significantly increased the practicality and value of training future crews.

The predictions expressed with regard to the possible requirements on training programs of astronauts in the simulator for the "Apollo" project indicated the necessity of creating various types of simulators (full profile, of part of the missions and of the mobile base).

During the creation of such simulator-training devices, the problem of the onboard computer system of navigation and control was specially solved.

The second problem which was allotted a significant amount of time was determined by the difficulties of visually simulating landing on the surface of the Moon.

Notwithstanding the fact that in this chapter primary attention has been /17
paid the experience which is acquired by crew members in the course of training in simulators, it does not in any case diminish the importance of systems of individual equipment. Doubtlessly, a large part of the difficulties in creating simulator trainers for all programs fall just to such equipment.

In the spring of 1961, when the first flight in the "Mercury" program had been completed, the duration of group astronaut training comprised two years. As has already been noted, before each flight the pilot and his standby participated in a program of preflight training. The duration of the course depended upon the time between flights and the missions of the flight. Frequently, the standby was named as first pilot for the upcoming flight which permitted a decrease in the period of the preflight course for each candidate by approximately 6 months: the first 3 months — the standby, the second 3 months — the primary pilot. Such a system is also characteristic for the Soviet space program.

The contribution of the astronaut-pilots in improving spacecraft systems began soon after they became adequately acquainted with the design of the "Mercury" spacecraft. As early as 1961, they participated in planning the subsequent "Gemini" and "Apollo" programs.

Each astronaut for a minimum of 3 weeks and longer was permitted to work in the capacity of a consultant with systems of the actual "Mercury" spacecraft. Upon completion of the program of group training, the astronauts changed over to developing flight skills to satisfy requirements manifested by the character of the flight.

Before the flight of the "Mercury-8" spacecraft in October of 1962, scientists were troubled by a problem: could the pilot determine the angle of yaw of a spacecraft using only the slow roll-by of the continents and clouds /18
visible from the spacecraft window in the capacity of correcting moments.

For this purpose, a trainer for determining the angle of yaw of the spacecraft was developed, built and used for training.

The model of the Earth panorama trainer consisted of a "Mercury" spacecraft cabin diminished in size by a factor of 2. This cabin had transparent walls and was mounted on cardin suspensions permitting 4 degrees of freedom. The trainer for determining terrestrial points of orientation consisted of the prototype of the pilot's chair, an actual periscope from the "Mercury" spacecraft, a screen for backward projection and a projector. In the trainer the astronaut became acquainted with the wide angle optical periscope which provides a compressed image of the outlines of shoreline, rivers, mountain ranges and other topographic elements. The trainer moved on an air bearing and had a free angle of turn of 360 degrees and free angles of pitch and yaw of 350 degrees. The height of movement was regulated during rollover along a cable by the aid of jet engines with low torque (which were used for regulating flight altitude in orbit for fuel economy).

For training in abandoning spcecraft in uncontrollable flight, a multiaxial trainer was used which had inertial rotation about its longitudinal axis.

As has already been said, part of the group training program was for training series of astronauts in the centrifuge. The first two series were of a familiarizing character while the second two series were the training sessions. The gondola simulated the interior of the spacecraft cabin, and both for orbital and ballistic flights the simulator of the altitude regulation system operated on the principle of the short circuit, since the rate of rotation was /19 assigned by the pilot. During the centrifuge run the astronauts were clad in spacesuits, and several series of rotation were carried out with simulation of an altitude of 8,500 meters (pressure 4.8 [Translator's Note: blank space in text] or 248 mm Hg). In all, the first astronauts had an average of 45 hours each of "flight" in the centrifuge. The training proved extremely useful, inasmuch as it became possible to test components of individual equipment and to demonstrate its possible functioning during the effect of g-forces; moreover, the astronauts had the possibility of developing skills, and increasing their resistance to g-forces. Hence, the program of training in the "Mercury"

project was the first experience of the USA, on the basis of which other programs were subsequently constructed.

The activity of astronauts and cosmonauts during spaceflights confirmed the adequacy of the preflight training programs. Further confirmation was obtained as the result of comparing working capacity when accomplishing various maneuvers in actual flight with the working capacity in training devices. Evaluations were also taken into account which were given by the pilots with respect to various training devices. After each flight the astronauts were subjected to an examination and a repeated investigation for comparing their working capacity before and after the flight. The astronauts reported, for example, that even if the sensation of weightlessness was generally pleasant, all the same, for adaptation both to the state of weightlessness and to the unusual view from the spacecraft window require a certain amount of time from them. Not one of these spaceflight characteristics can be adequately simulated under terrestrial conditions. And notwithstanding the fact that the period of adaptation to the unusual conditions of flight can be diminished, and the view from the spacecraft window improved, the astronauts view these problems as very serious ones.

The pilot astronauts unanimously confirmed the importance of their participation in improving the spacecraft systems on the eve of the flight. A general opinion was expressed that the centrifuge is the most useful device for training and that the experience accumulated as the result of the centrifuge runs prior to the flight is very valuable. /20

The flight of the "Gemini" spacecraft was the next stage in the development of the manned orbital flight programs. Notwithstanding the fact that the results of the flights of the single place "Mercury" spacecraft, as well as the observations of Soviet cosmonauts had demonstrated the capacity of man to live and work in orbit, the program of flights of the two place "Gemini" spacecraft posed its own problem (in addition to others) of verifying the physiological capacities of the human organism to live and work in space over the course of a period of time necessary for flight to the Moon and return to the Earth, as well as to carry out operations in open space.

Elements such as checking systems for maneuvering and docking in space also had to be introduced into the program of training of the lunar expedition.

Proportional to accomplishment of the "Gemini" program, planning and training pilots and new groups of astronaut scientists for the "Apollo" project were carried out. All the concepts expressed here had great influence on the character of astronaut training.

Training pilots and astronaut scientists for the "Gemini" and "Apollo" programs went on simultaneously.

The flight crews had to accomplish a series of missions which consisted in working out skills in navigation, in flight trajectory correction, as well as in making a landing on the Earth and on the surface of the Moon. They also had /21 to be able to check systems and to launch themselves from terrestrial orbit, from the orbit and surface of the Moon, using only the readings of the onboard instruments and information transmitted by radio from the Earth.

In participating in spacecraft tests, the crew members acquired experience and skills in piloting. In the course of the trials of the "Gemini" spacecraft, all the astronauts spent from 40 to 50 hours each in the cabin and an even greater amount of time was devoted to observation and development of specific details.

The "Gemini" program showed that high working capacity and effectiveness of crew activity during flight along a terrestrial orbit on the whole depended upon the quality of preflight simulator training. The experience of the flights showed that the simulator trainers, for the most part, accurately dupplicated the conditions of real spaceflight.

For simulating the conditions in which the astronaut would be active during his exit into open space, planned for the flights of the "Gemini-11" and "Gemini-12" spacecraft, a dynamic training device was created for working out crew actions. By the aid of this trainer, basic schedules and control assignments for making the walk in space were developed, while the capacity of the crew to fulfill these missions was determined.

Preliminarily, crew training to activity under ordinary and emergency situations was carried out in the trainer. The actions of the crew upon breakdowns of various onboard systems were worked out.

The presence of various simulators made it possible almost fully to duplicate conditions of the flight of the "Gemini" spacecraft. The successful /22
accomplishment of all the flight missions by the spacecraft crews was a direct consequence of training in stimulator trainers of high quality.

The results of the "Gemini" program provided scientists and engineers with the necessary amount of information for accomplishing crew training which made possible successful embodiment of the program for landing on the surface of the Moon. The crew members of the "Gemini" spacecraft showed that man can be under conditions of weightlessness for a period of 14 days (which by a factor of 2 exceeded the time minimally required for the lunar expedition); the astronauts checked the developed methods of approach and docking which were a vital part of the "Apollo" program; the experience of the astronauts also confirmed the concept in accordance with which, for refueling future spacecraft capable of docking in space, a special auxiliary spacecraft could be placed in orbit. The astronauts also showed the possibility of comparatively long term activity of man in open space and the capacity for crew members to accomplish various missions outside the spacecraft. All this was the prelude to the actual flight to the Moon.

As has already been shown, both astronaut pilots and astronaut scientists who trained together for flights in the "Gemini" spacecraft were selected to participate in this program; training was modified proportional to improvement in spacecraft design and the astronauts worked on both skills which they had acquired earlier and learned to carry out new operations.

The crews of the "Apollo" spacecraft went through a comprehensive practice in fulfilling all nominal and unplanned flight situations on one of the trainers.

Accomplishing many varied missions which have not been included in the /23
official program entered the training program; these were as follow: a) unofficial actions of astronauts having personal motives (study, physical conditioning); b) training for ordinary flights (piloting aircraft, etc.); c) crew

actions directed to aid personnel who had prepared for a certain flight or for the "Apollo" program (spacesuit fit, medical examination, recruiting candidates, travel, recording flights, solving engineering problems and other problems).

In conclusion one can note that training of the Soviet cosmonauts and American astronauts for participation in manned flights was structured (with the exclusion of certain cases) according to a single logical model. In both countries the methods of training devolved from already known aviation experience and embodied additional requirements which had been developed as the result of extrapolation of this experience to the new conditions. Inasmuch as all candidates were experienced pilots before the beginning of training, people who could adapt to severe conditions of high velocity high altitude aircraft flights, the main medical problem which required solution consisted in studying the influence of spaceflight factors. Later, in proportion to the accumulation of actual experience during orbital and spaceflights, it became possible to determine the requirements made on spacecraft crews. It was shown that crew members need not only be trained test pilots (which was characteristic for the first manned flights of the USSR and USA), but could also be scientists and engineers.

Over a period somewhat in excess of 10 years, which is covered in this chapter, preflight and flight training of crew members was relevant to ground training and also the accumulating experience in the course of orbital flights. /24

Training men to participate in prolonged spaceflights will have its peculiarities. For this, the united efforts of representatives of all the space sciences, basic and applied, and both occupied with problems of man and not occupied with them, including the many intermediate disciplines — the biological sciences, molecular sciences, chemical sciences and behaviorial sciences are required. More than anything else it is vital to recognize that man is a rational dynamic "subject" and not an "object" to be evaluated merely by means of physical and engineering criteria.

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